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Consequences of Cathodoluminescence for Cryogenic Applications of SiO_2-based Space Observatory Optics and Coatings

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Abstract

Disordered thin film fused silica samples undergoing electron-beam bombardment exhibit cathodoluminescence, which shows increased intensity and red-shift at lower temperatures. Such light emission from SiO_2/SiO_x optical elements or coatings can be beneficial. Alternately, it can produce deleterious stray background light in cryogenic space-based astronomical observatories exposed to high-energy electron fluxes from space plasmas. Calculations are presented of absolute spectral radiances for flux profiles over incident electron energies typical of space environments; these allow prediction of luminescence for specific space applications.

Measurements of absolute radiance and emission spectra as functions of incident electron energy, flux, and power were made for thin (~60-200 nm) coatings on reflective metal substrates over a range of sample temperatures (~40-400 K) and emission wavelengths (~260-1700 nm). Radiance exhibited saturation at high incident power. Well below saturation, radiance scaled linearly with incident power for lower-energy non-penetrating radiation, but decreased with incident energy for higher penetrating energies (where only a fraction of their energy is deposited in the dielectric film). Overall, radiance increased at lower temperatures. However both intensity and peak wavelengths of four distinct bands observed in UV/VIS/NIR emission spectra, ranging from 300 nm to 1000 nm, showed dissimilar behavior with increasing temperature.

Our measurements are explained with simple disordered band theory models for electron transport in highly disordered insulating materials, which provide a fundamental basis for understanding the dependence of cathodoluminescence on irradiation time, incident flux and energy, sample thickness, and temperature. It also models saturation effects in terms of a competing thermal process involving radiation induced conductivity.